Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

Earth System Services Group
Earth Sciences Department

Seasonal climate prediction for the wind energy sector: methods and tools for the development of a climate service

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Jornadas Doctorandos – Universidad Complutense de Madrid
15-17 March 2017

Wind predictability at different time horizons

Weather forecasts

1-15 days

Climate predictions

10-32 days | 1-15 months | 2-30 years

Sub-seasonal | Seasonal | Decadal

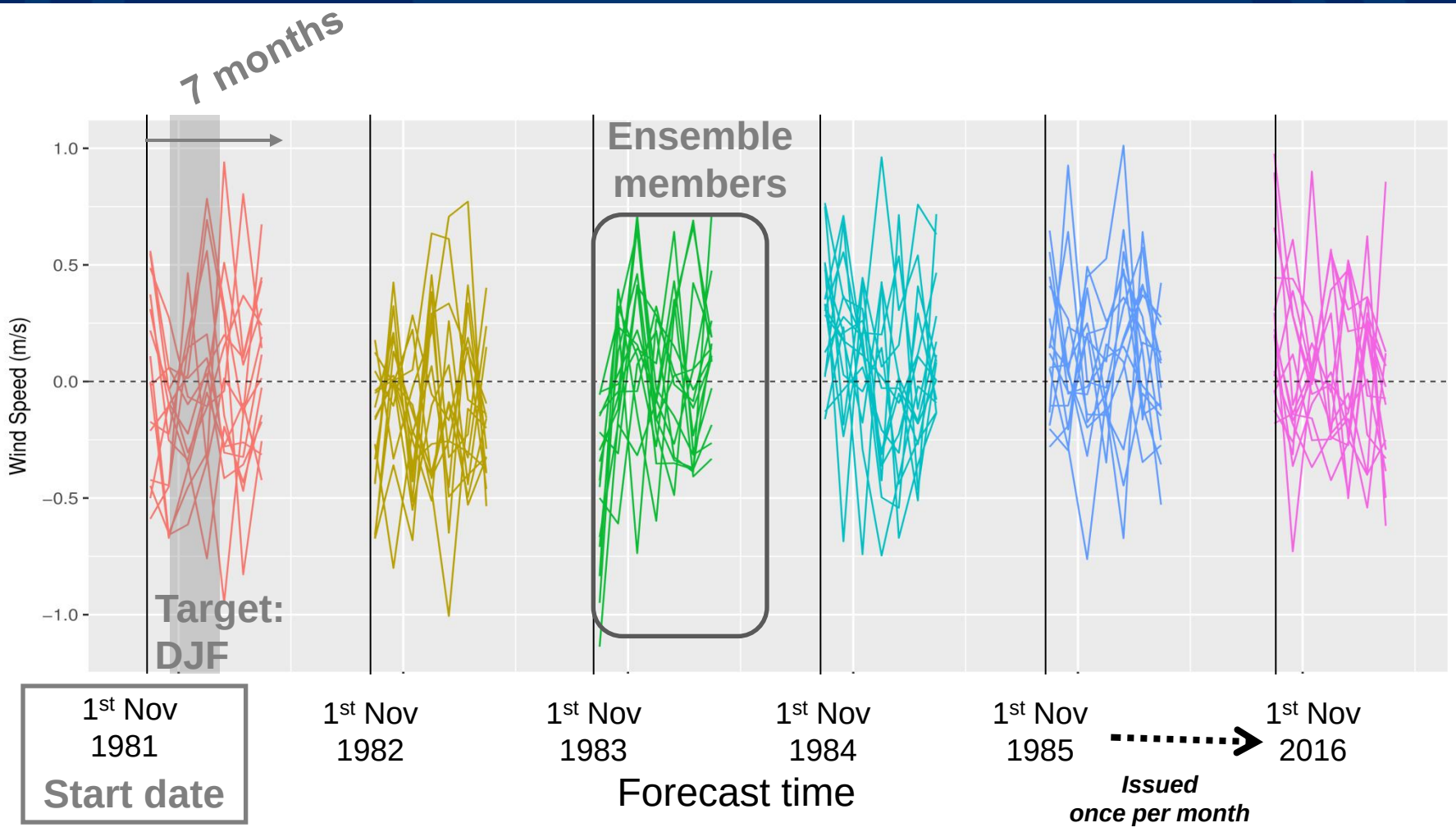
Climate projections

20-100 years

The available seasonal predictions can provide additional value for wind energy applications

- Maintenance works
- Grid management
- Financial issues

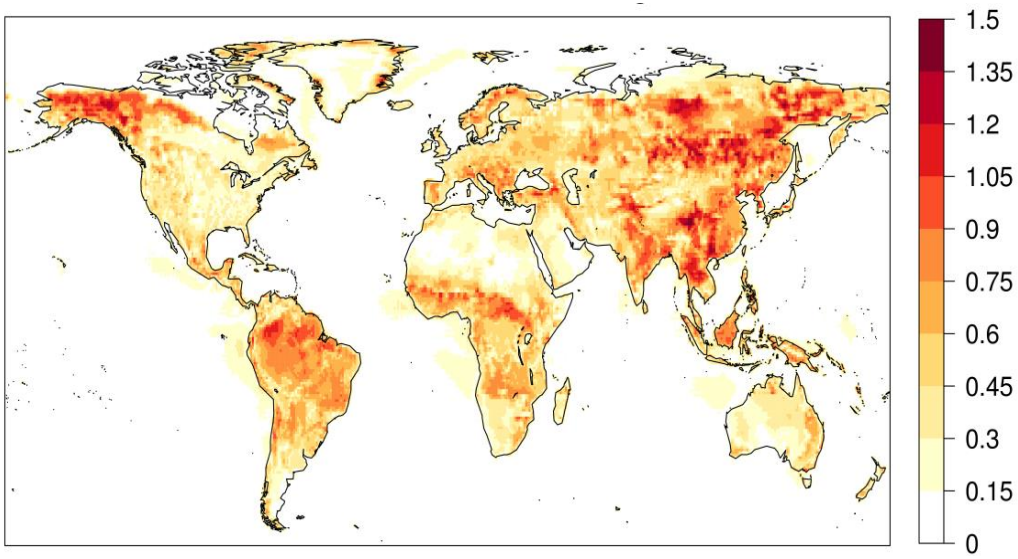
ECMWF S4 probabilistic seasonal predictions



Hindcasts (1981-2010)

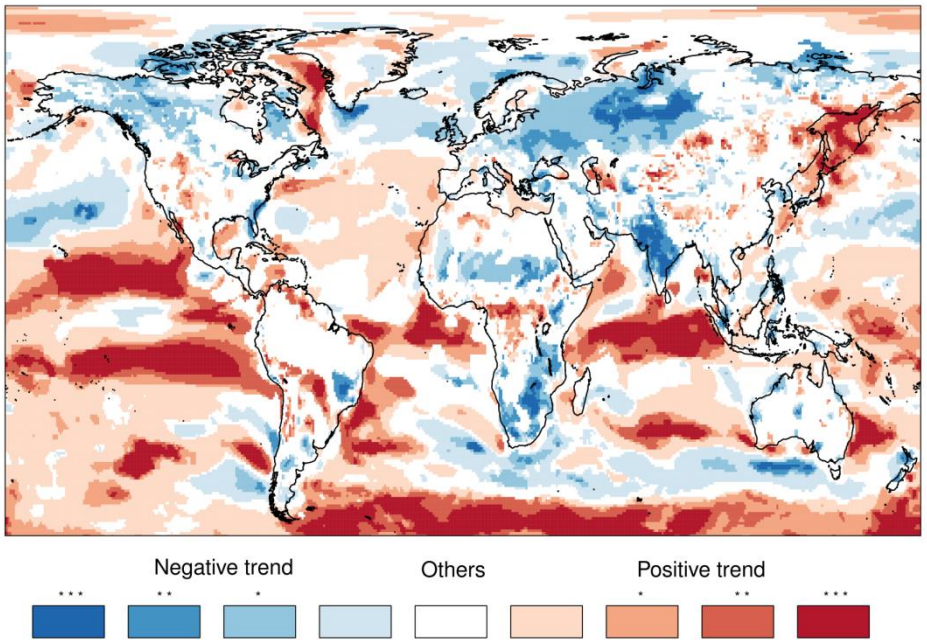
Forecasts (2011- now)

Challenges for the use of climate information: Observational uncertainty

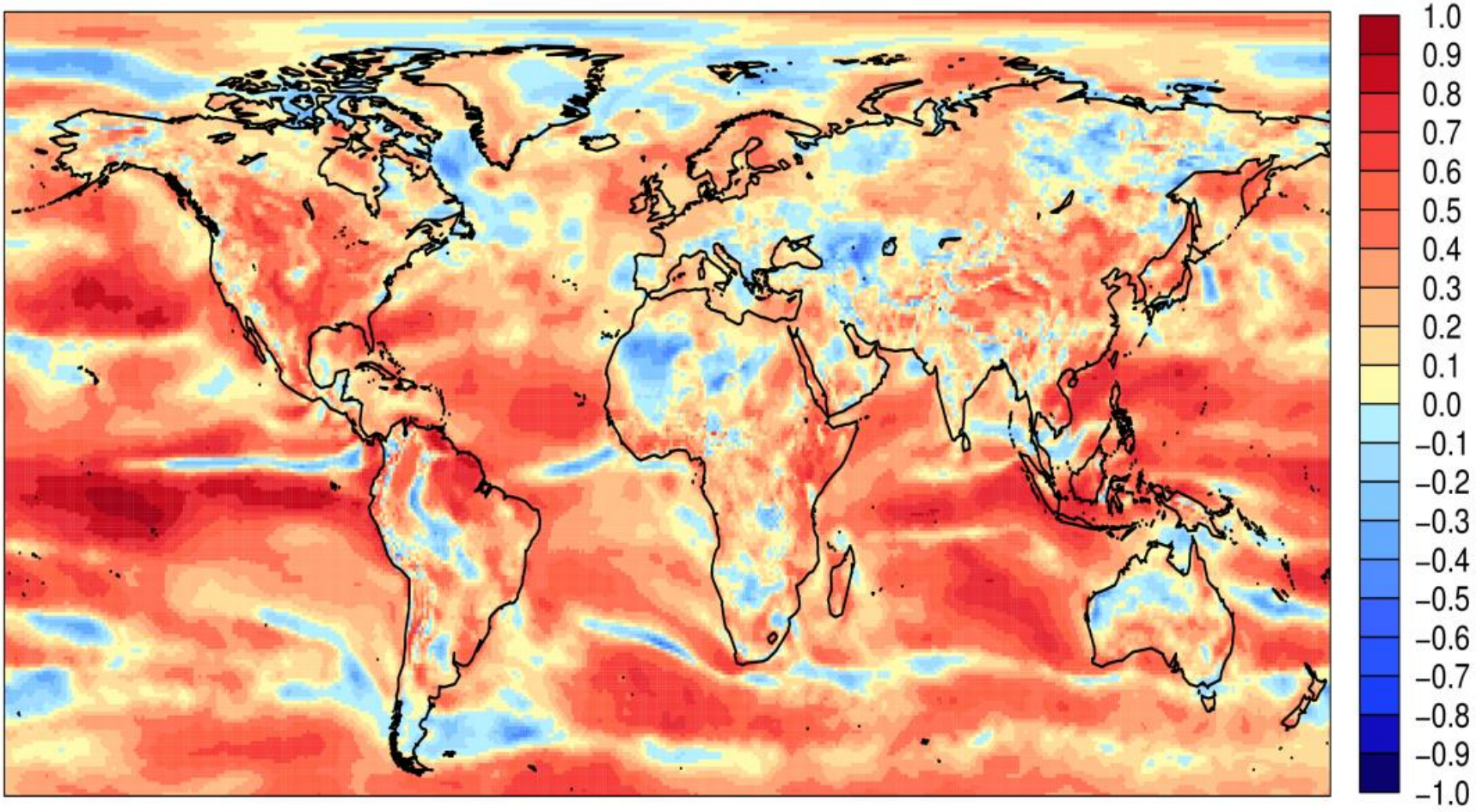


Range of the differences (m/s) between the 10-m wind speed values produced by ERA-Interim, MERRA-2 and JRA-55 reanalyses.

Coherence maps of the 10-m wind speed trends (m/s) in the ERA-Interim, MERRA-2 and JRA-55 reanalyses.

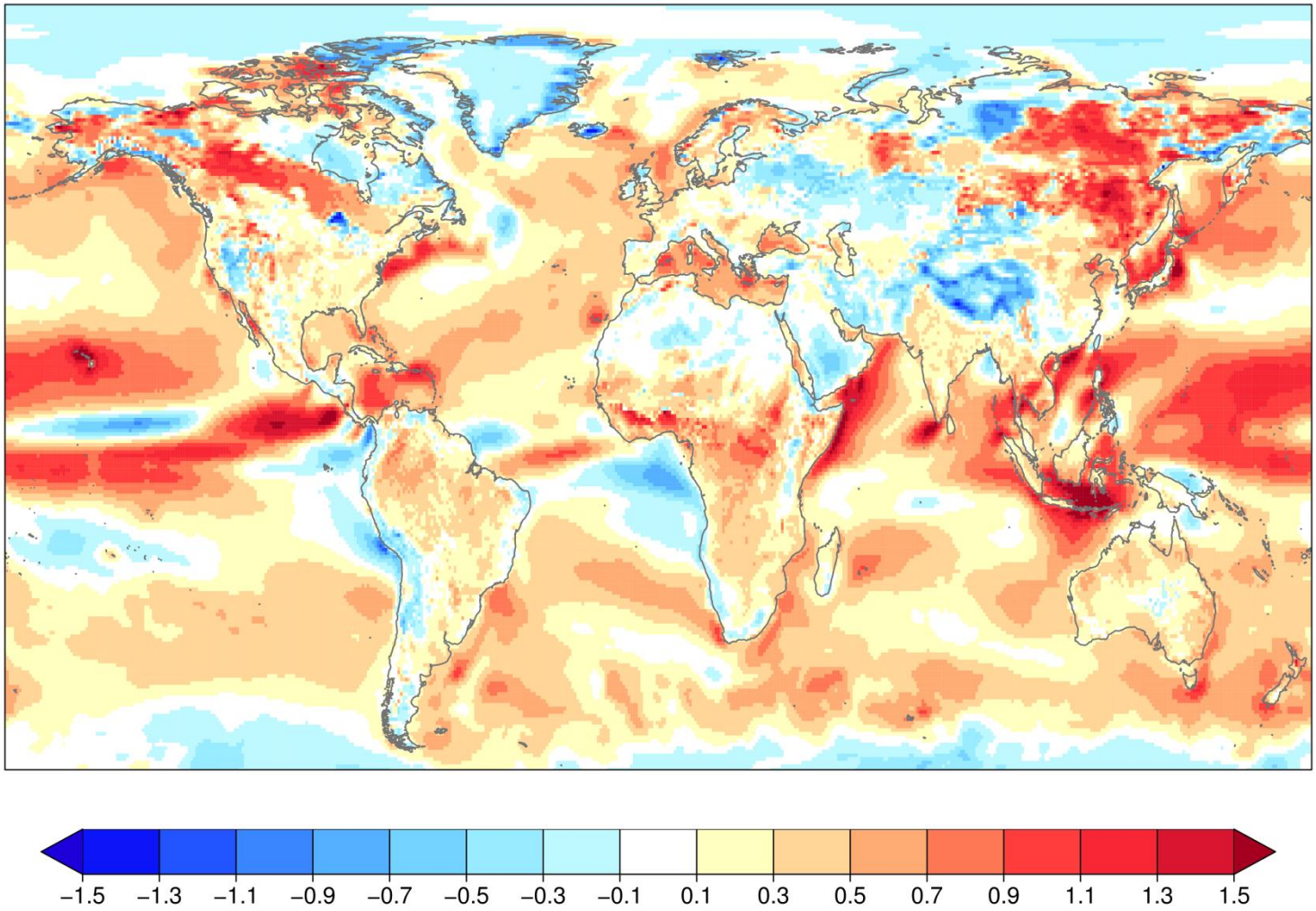


Challenges for the use of climate information: Predictability



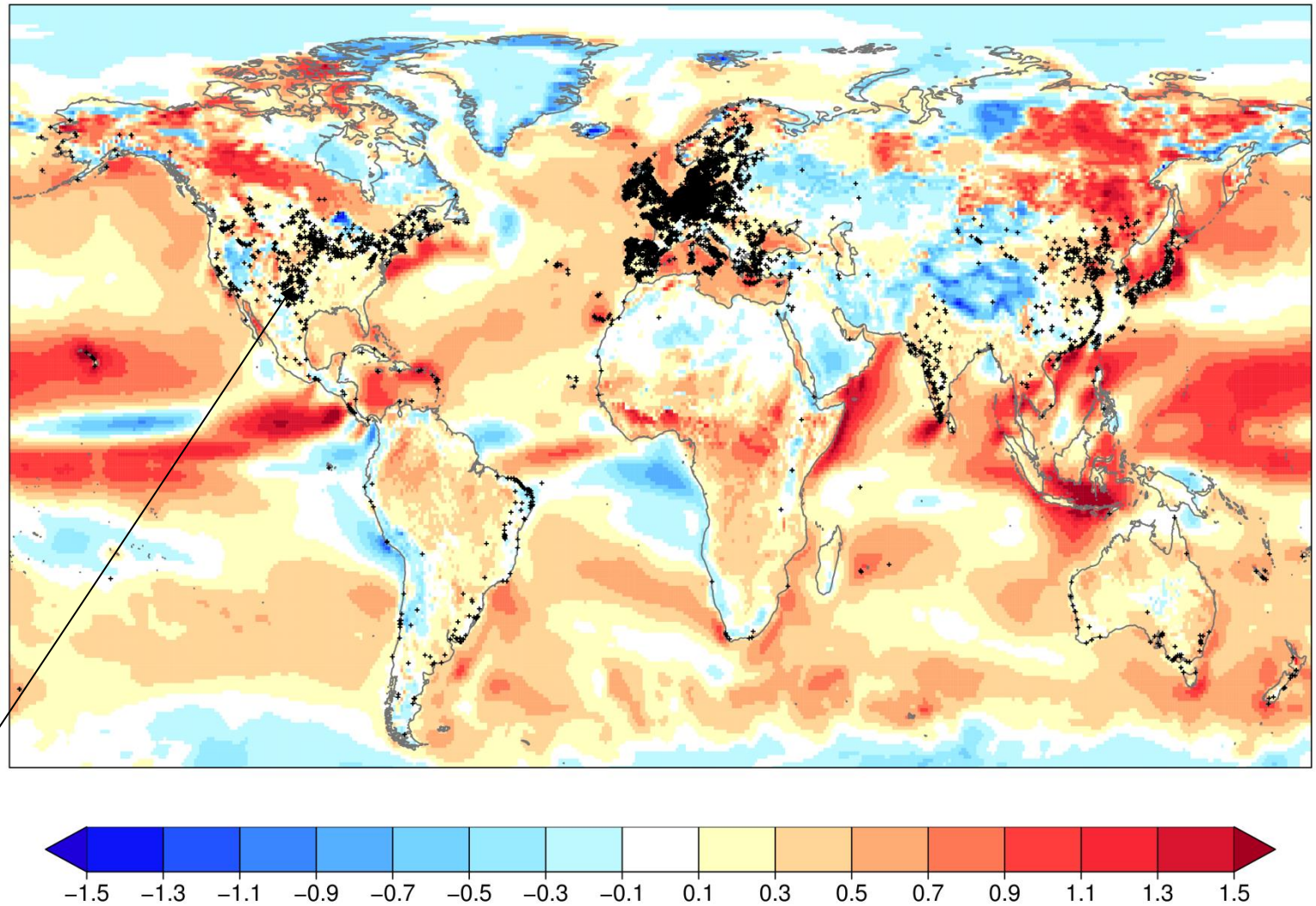
Correlation for 10-m wind speed between the ensemble mean forecasts from ECMWF S4 and ERA-Interim reanalysis in winter

Challenges for the use of climate information: Biases



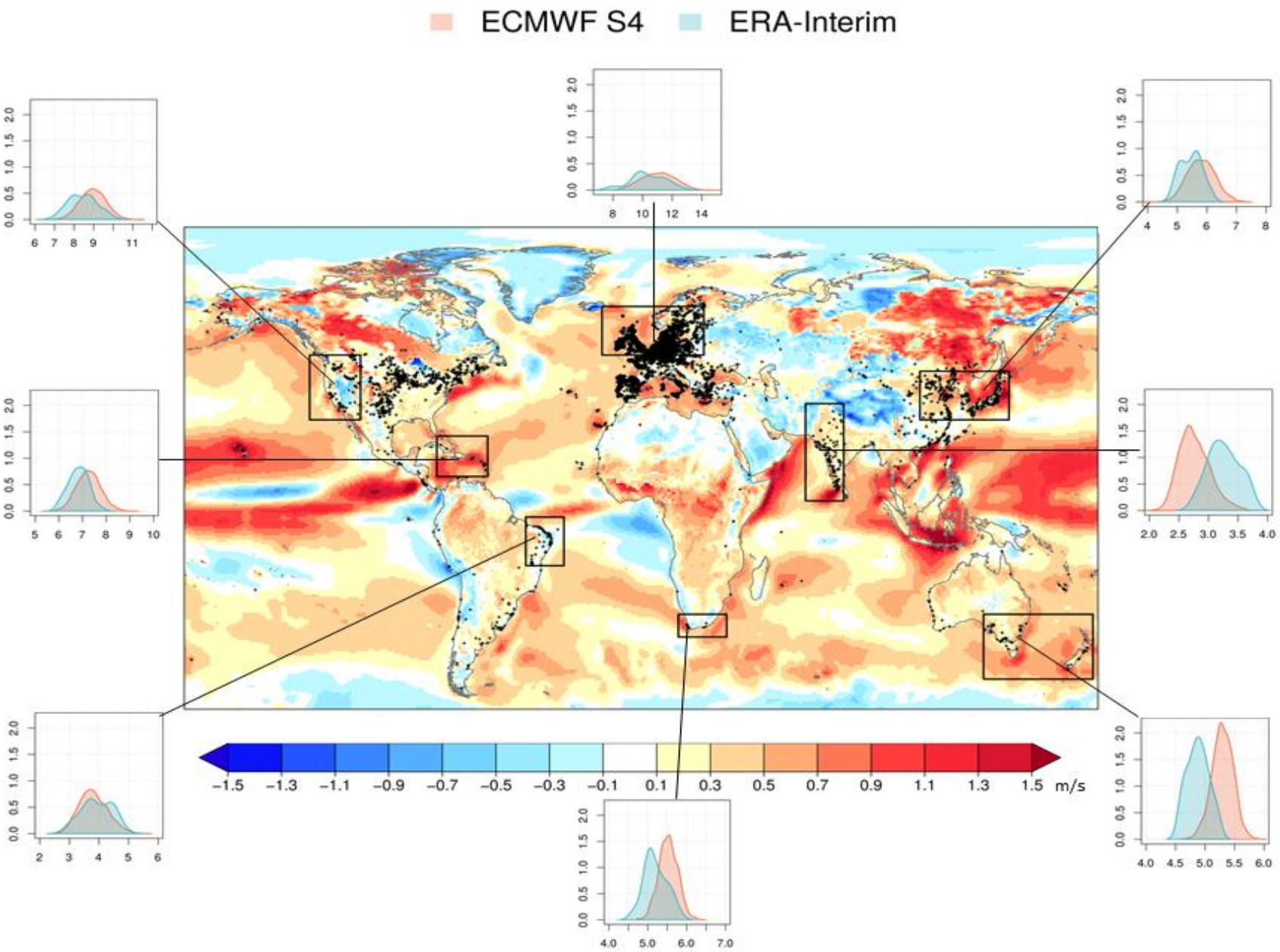
Bias of 10-m wind speed between the ensemble mean forecasts from ECMWF S4 and ERA-Interim reanalysis in winter.

Challenges for the use of climate information: Biases

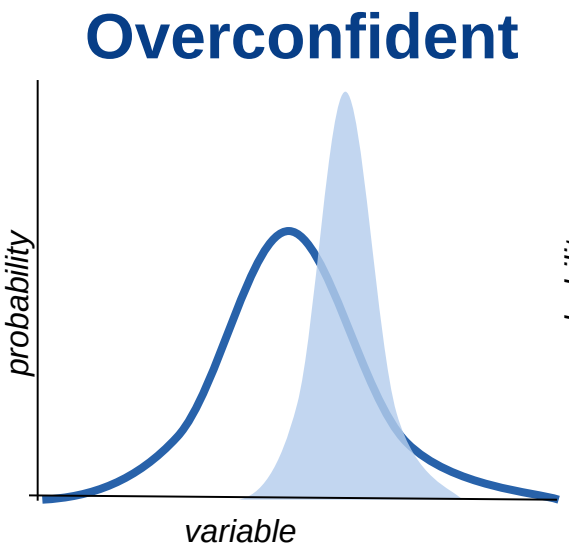


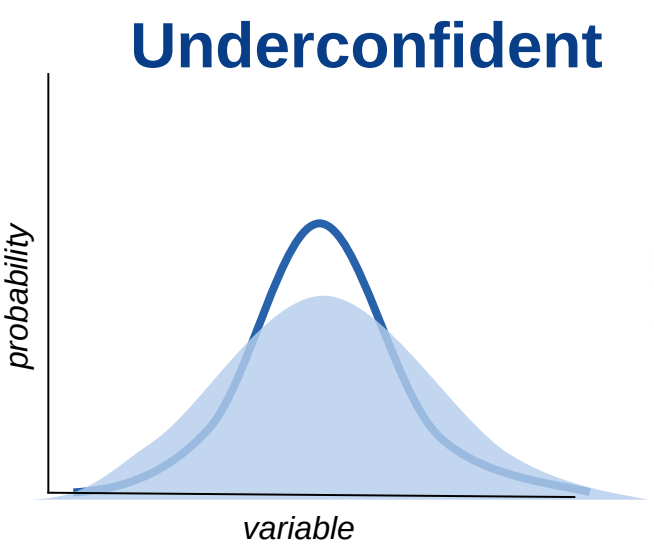
Installed wind farms

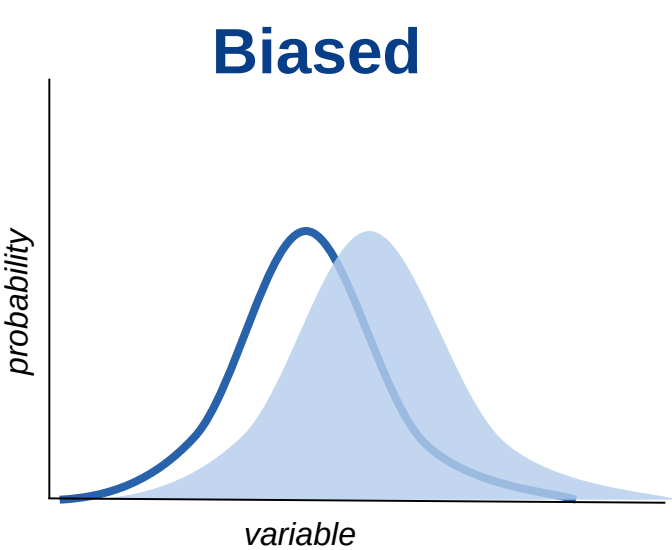
Challenges for the use of climate information: Biases



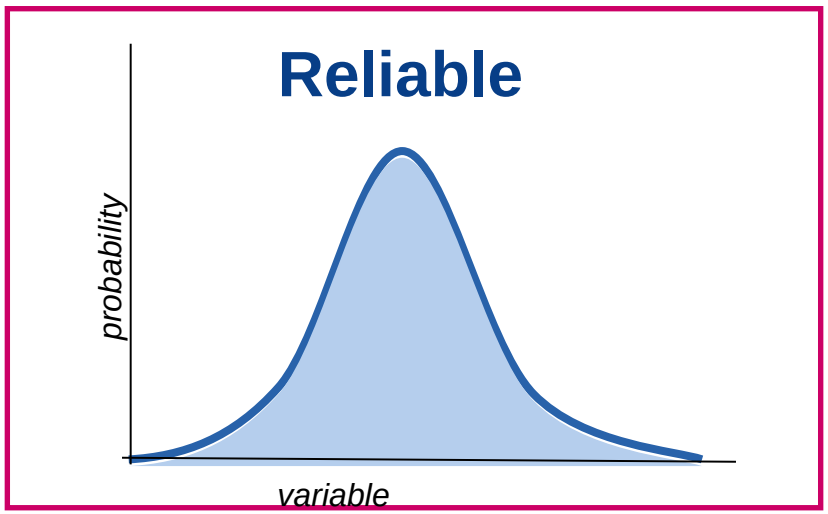
How to develop useful information?







Bias adjustments



Bias-adjustments

Simple bias correction	Calibration method	Quantile mapping

$$y_{j,i} = (x_{ij} - \bar{x}) \frac{\sigma_{ref}}{\sigma e} - \bar{o}$$

Variability Observations

Variability Ensemble

Simple bias correction is based on the assumption that both the reference and forecasted distribution are well approximated by a Gaussian distribution.

Leung et al. (1999)

Bias-adjustments

Simple bias correction	Calibration method	Quantile mapping

$$y_{j,i} = \alpha x_i + \beta z_{ij}$$

Variability Observations

$$\alpha = |\rho| \frac{\sigma_o}{\sigma_{em}}$$

Variability Mean Forecast

$$\beta = \sqrt{1 - \rho^2} \frac{\sigma_o}{\sigma_e}$$

Variability Esemble

Variance inflation:

- Predictions with the same interannual reference as the reference dataset
- Correction of the ensemble spread.

Von Storch (1999)
Doblas-Reyes et al. (2005)

Bias-adjustments

Simple bias correction | Calibration method | **Quantile mapping**

$$y_{j,i} = ecdf^{ref-1} ecdf^{pred}(x_{ij})$$

Inverse cumulative density function of the reference (quantile function)

Cumulative density function of the predictions

Determines for each forecast to which quantile of the forecast climatology it corresponds, and then maps it to the corresponding quantile of the observational climatology.

Themeßl et al. (2012)

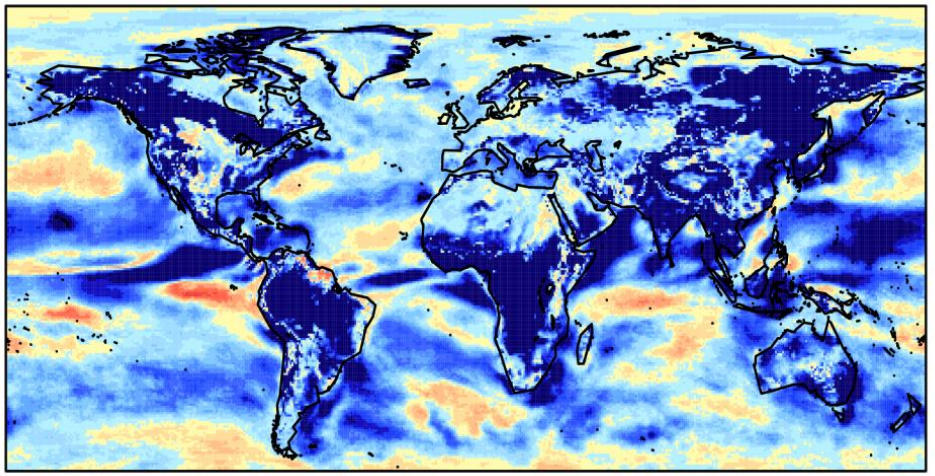
Impact of bias-adjustments on skill

Ranked Probability Skill Score

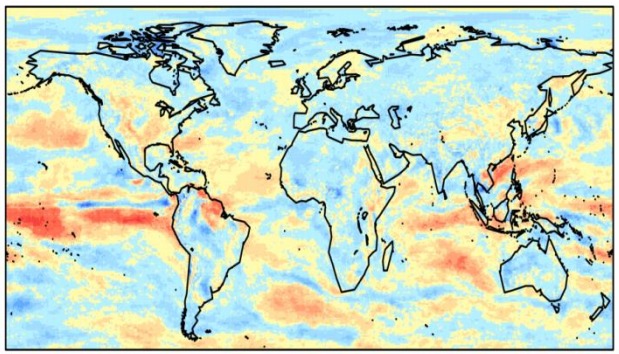
$$RPS = \frac{1}{M-1}\sum_{m=1}^{M}\left[\left(\sum_{k=1}^{m} p_k\right) - \left(\sum_{k=1}^{m} o_k\right)\right]^2$$

$$RPSS = \frac{\overline{RPS} - \overline{RPS}_{reference}}{0 - \overline{RPS}_{reference}} = 1 - \frac{\overline{RPS}}{\overline{RPS}_{reference}}$$

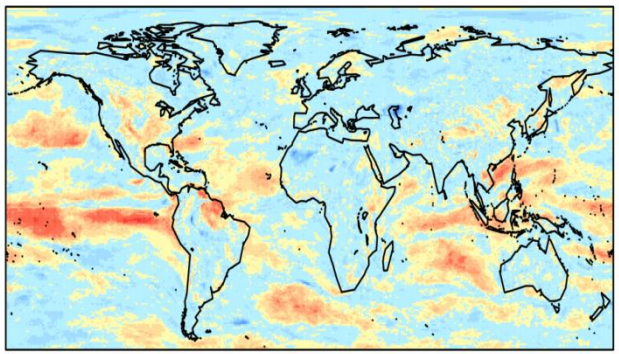
Uncorrected



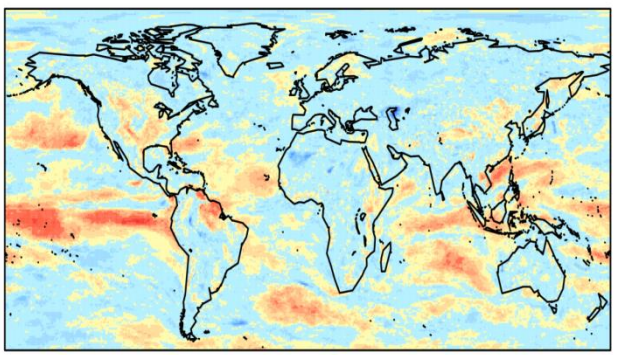
Simple

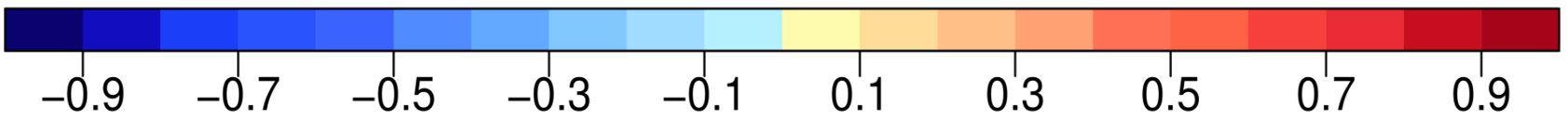


Calibration

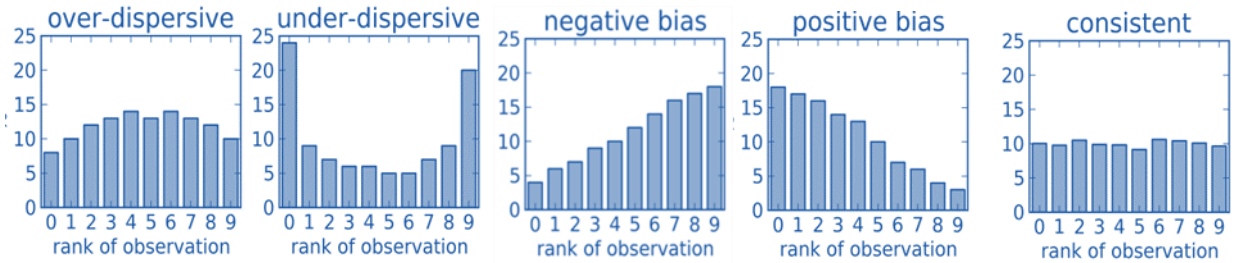


Q-Q mapping

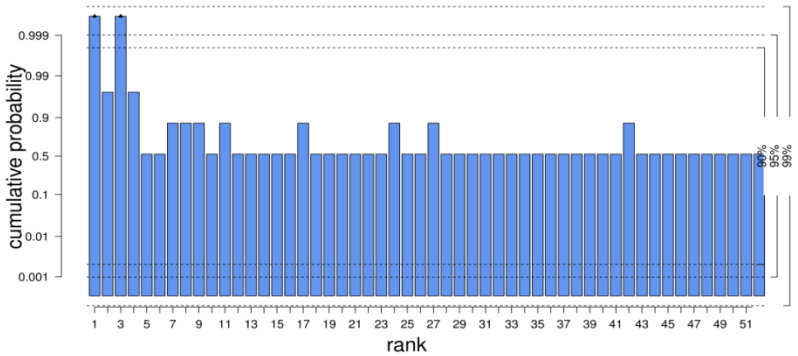




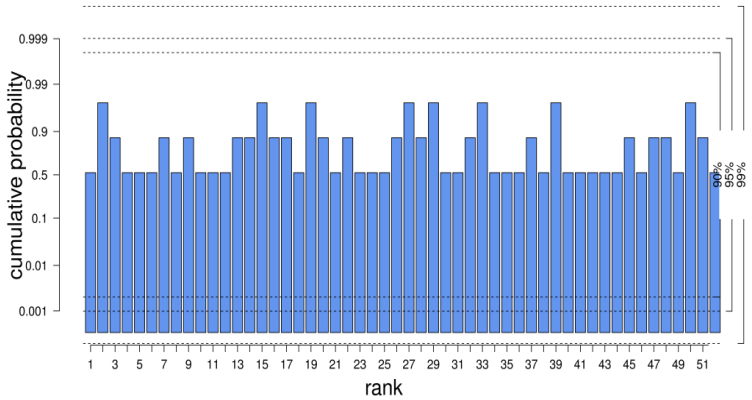
Impact of bias-adjustment on statistical consistency



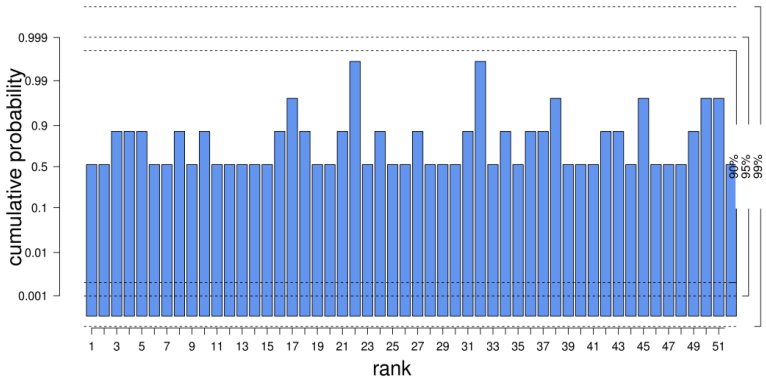
Uncorrected



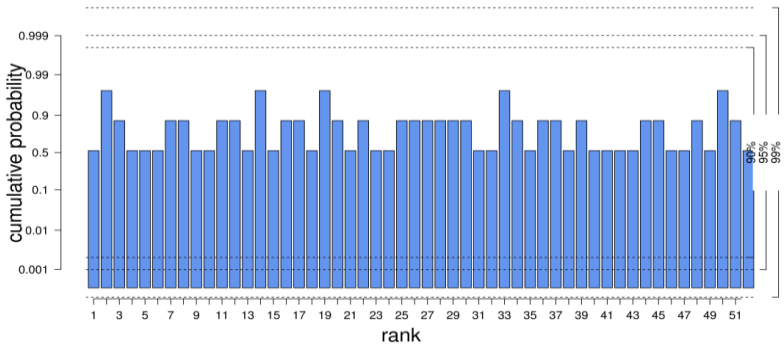
Simple



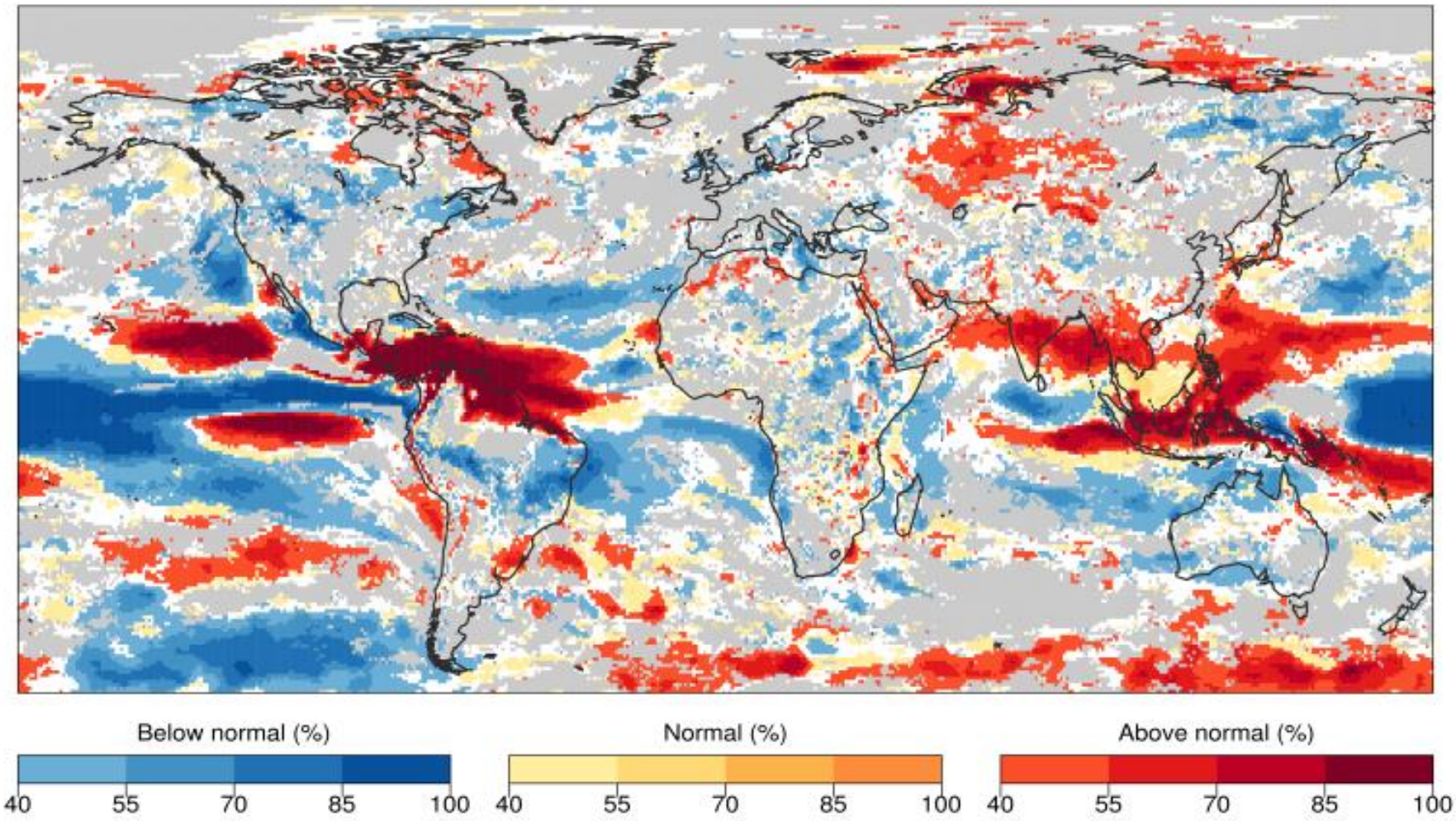
Q-Q mapping



Calibration



Tailored wind speed predictions



ECMWF S4 10-m wind speed seasonal forecast for DJF 2015 initialized the 1st of November. The most likely wind speed category (below-normal, normal or above normal) and its percentage probability to occur is shown. White areas show where the probability is less than 40 % and approximately equal for all three categories. Grey areas show where the climate prediction model doesn't improve the climatology.

Conclusions

- Methodology to develop **useful information for the wind industry**

  Torralba V., Doblas-Reyes F.J, MacLeod D., Christel I. and Davis M. (2017) Seasonal climate prediction: a new source of information for the management of the wind energy resources. Journal of applied meteorology and climatolgoy.

- Three methods of bias correction (which are simple enough to be understandable for the users) have been used to produce forecasts with **improved forecast quality**

- Calibration method displays **better reliability** than simple bias correction and quantile mapping, however in terms of skill the three methods produce similar results

- Future work will focus on:
  - Predictions for specific sites
  - Impact model to produce seasonal predictions of wind power capacity factor